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THE ELECTRICAL CHARGE OF THE EARTH'S SURFACE

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[Figures referred to herein are appended.]

As is known, the basic problem of atmospheric electricity, which causes the earth's surface to remain charged, has not yet been solved in spite of a number of hypotheses more or less explaining one or another aspect of this question.

The main difficulty encountered in the solution of this problem is the lack of experimental material, and for this reason it is necessary to resort to various assumptions which cannot always be confirmed under the actual conditions of the atmosphere and the earth's surface.

All new material drawn from observations, and which was hitherto unknown, may serve as a supplementary argument in relation to some hypothesis which is based, more or less, on modern ideas.

In this connection consider as acceptable, but not in every case proved, Wilson's hypothesis (1), supplemented by Vigand and recently by Whipple and Scrase on the basis of experimental work done by Wormell (2) and Schonland.

The same can be said of the recent hypothesis evolved by Ya. I. Frenkel' (3), based on the recent experimental work of Simpson and Scrase (4) and on modern colloid-electrochemical concepts, and also on the corresponding physical-mathematical considerations. This hypothesis presents an original viewpoint regarding phenomena and processes connected with the reduction of the earth's electrical charge. These two hypotheses, which differ in principle with regard

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to the mechanism of the actual process connected with the charge of the earth's surface, originate from the same essential point that the "counter-current," the amount of electricity compensating the inflow of positive electricity to the earth's surface, occurs in so-called "disturbed" regions, where the electrical field of the earth, under certain conditions, has a direction opposed to the one existing in the regions of "fair weather." Both of the cited hypotheses consider zones and periods of storm precipitations or storm cloudiness as being such regions.

Schweidler, one of the more competent investigators in this field, gives a more precise definition of these areas with abnormal electric field values. According to him, such areas may be expediently divided into two classes:

1. Areas in which the energy of the field is directed upwards ("areas of negative potential gradients"), but where, as far as absolute quantity is concerned, the energy does not exceed the normal values, and in which this disturbance continues for a relatively long time; such areas, for instance, include regions with continuous precipitation.

2. Areas in which the energy of the field changes quickly and irregularly, at the same time assuming absolute values which, compared with the normal values, are enormous; this occurs during precipitation of a squally character and, above all, during thunderstorms.

Furthermore, in analyzing these two instances, Schweidler comes to the conclusion that these processes in disturbed areas are not sufficient to compensate for the positive charge approaching the earth's surface. Schweidler considers that the experimental work of Wormell (2) provides a good explanation of this fact. Wormell has measured quite large currents during atmospheric-electrical disturbances which originated from point discharges. By evaluating the integral (with respect to time) of the current leaving a rod 8 meters high, with the point upwards which Wormell considers as a tree model, he comes to the conclusion that there is a sufficient amount of electricity, in the form of "countercurrent" in the disturbed areas, to compensate for the conductivity current on the whole of the rest of the earth's surface. However, the "balance," which he expresses as the surplus of countercurrent of 40°C, determined for Cambridge and extrapolated for all disturbed areas, is hardly based on strict principles.

In this connection, the following observations on the Fedchenko glacier (experiments on the glacier were made in the course of two winters, 1939-40 and 1943-44, by the head of the station, S. P. Cherptanov, under the general and methodical supervision of the author), by means of which considerable values of the reversed electrical field were disclosed in the course of prolonged periods of time, may offer three items of supplementary material: (a) there are areas on the earth's surface providing "countercurrents" even in the absence of storm activity; (b) the "countercurrent" in such areas is considerable in quantity and continues for a long time; and (c) the "countercurrent" is not connected with the daily periodicity of thunderstorm processes in areas of the greatest storm activity (which is, for instance, the basis of the Whipple and Scrase hypothesis, on the daily course of the gradient of electrical potential).

In this way, the two cited statements of Schweidler may be supplemented by a third one.

3. There are areas in which the voltage of the electrical field changes considerably, assuming great negative values, up to tens of thousands of volts per meter; such reversed electrical fields exist continuously in the course of 24 hours and are of long duration.

I now proceed to prove this statement. The existing results of observation during snowfalls, show that the electrical potential gradient in the atmosphere is considerably raised and remains positive. These

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observations agree from both the middle latitudes and the northern polar regions, where snowfalls are a common occurrence during the greater part of the year.

A different situation occurs during snowfall on the Fedchenko glacier, a high mountain observatory in the Kirghiz region.

During snowfall, especially with strong winds exceeding 7-8 meters per second, the gradient of electrical potential assumes negative values, more than 5400 volts per meter, the limit valued of low sensitivity on Bendorf's electrograph (at the observatory).

By way of illustration, the diagram, (Figure 1) gives the comparative course of gradient during snowfall on a single day, 29 December 1943, in Tashkent and on the Fedchenko glacier, registered by the same type of recording device.

From the lines relating to the daily course of the gradient of the electrical potential (in both cases during snowfall), it can be seen that while in Tashkent the gradient has a positive value, on the Fedchenko glacier the same element assumes a negative value, increasing with the wind velocity. At the same time, during wind velocities of less than 8 meters per second, the gradient has the usual positive values.

This is characteristic for the Fedchenko glacier during all periods of snowfall, not for 24 hours but for months and entire seasons, i.e. actually during the greater part of the year.

The lines on Figure 2 which show the gradient of electrical potential in relation to wind velocity, illustrate the above statement. The electrical field least connected with snowfall has normal values, only during the period June to September. Through two other periods, October to January and especially February to May, during snowfalls coupled with high winds, their velocity sometimes reaching 18-20 meters per second and more, the electrical field has reversed values, and the gradient of the electrical field assumes values up to several thousand and more volts per meter.

In this connection it is interesting to compare the gradients of electrical potential under the same conditions of snowfall and corresponding wind velocities on Dickson Island (5) (Figure 3).

The lines showing variation in electrical potential gradient on Dickson Island, by the same self-recording device (Bendorf's) give only positive values, and, just as on the Fedchenko glacier, they increase with the wind velocity, and this prevails throughout the year.

Thus, the electrical field during snowfall differs radically, both in size and especially with regard to its negative value on the Fedchenko glacier, from fields in the flatlands of various latitudes, for example, in Tashkent or on Dickson Island.

The explanation of this anomalous phenomenon, considering the underlying surface of the Fedchenko glacier and the orographic conditions of the observation point location may, in my opinion, be summarized as follows:

First of all, let us remark that the underlying surface, on which the observatory and the atmospheric electricity observation point are located, borders upon an immense glacier field, into which some smaller glaciers flow, chiefly from the south.

Surrounded by mountains, particularly high on the west and southwest, the meteorological station is located opposite the great Kashalayak pass in the Pamir area (in the direction southwest-west) from where strong winds blow, bringing masses of snow from the surrounding glaciers (Figure 4).

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Observers report that during heavy snowfalls it is hard to determine the source of the snow, i.e., whether it falls from the atmosphere or whether it drifts from the ravine and the surrounding mountain peaks (e.g. Peak "MYuD" and others).

Winter observations made by the Station Head, S. P. Cherptanov, on the Fedchenko glacier indicate that the transition of the electrical potential gradient from positive to negative values takes place under two conditions: during heavy gusts of wind, which raise the snow from the surface and, especially, at times when the snow is carried over by strong air currents (winds over 10-12 meters per second) from the glaciers or mountain configurations surrounding the station, which are covered with ice or eternal snow. During calm periods, when the snow falls from a free atmosphere, the gradient assumes positive values (a good illustration of this is the curve of daily variation in Figure 1). According to S.P. Cherptanov, this is shown so clearly that it is possible to judge by the electrograph needle whether the snow is falling, or being carried over from glacier fields, or rolling down the mountain slopes covered with eternal snow. Hence it is natural to connect the negative values of the electrical potential gradient with certain wind effects and the character of the falling or windborne snow.

Some time ago, Rugge (6) and later Kähler (7), explained the positive, and usually increased value of the gradient of electrical potential during snowfall as being caused by the formation of space charges due to minute particles of snow being broken off from snowflakes, especially during snowstorms. These particles are charged with negative electricity and are carried upwards; the rest of the snowflake, charged positively, descends, thus causing positive space charges. In this way, the charges are divided and the positive field of the atmosphere is increased. Under ordinary conditions of the underlying surface, this charge is transmitted to the earth and is neutralized. However, under the conditions prevailing on the Fedchenko glacier, the positively charged snow, falling on a solid massive layer of snow (thickness 0.40-0.50) evidently keeps its charge, especially when the snow is on a glacier foundation.

If this is, indeed, the case, the observations and recordings become understandable and explanatory, giving negative values of the electrical potential gradient under certain conditions of snowfall (or, more correctly, the drifting over of snow).

In this case, the electrical potential gradient observed on the Fedchenko glacier might be explained as follows.

As cited above, the winds blowing on the Fedchenko glacier around the station are usually (especially during snowstorms) west-southwest, coming from the Kashalayak pass, which is located near the glacial boss and 100-150 meters above it. During snowstorms the wind drives the snow along in the form of an avalanche or snowdrift (the latter may also occur from local winds). This snow is charged positively, as usual. Hitting the station from the snow or windward side, where the collector (the receiving part of Bendorf's electrograph, which registers the voltage of the electrical field) is located, the snow charged positively, accumulating on the boss, (especially under the collector) reverses the direction of the electrical field from below upward.

On the other hand, minute particles, breaking off the more easily the stronger the wind, are carried upwards, charging the lower part of the cloud formations which are usual during snowstorms on the Fedchenko glacier, and in this way influence the electrical field of the atmosphere in the same direction as the positively charged masses of snow below.

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In this way, a sort of "condenser" is formed with the positive side (the surface of the snow) underneath.(The positive charge of a snow surface has been noted by V. I. Gerasimenko (8), who carried out research on atomospheric electricity on Cape Chelyuskin. According to Gerasimenko, he repeatedly observed a potential difference between the grounded body of the electrometer and the thread connecting it with the snow surface.). The negatively charged layer of the lower part of the clouds above is, as it were, the negatively charged side of the same condenser.

The height of the collector is, relatively speaking, considerable (up to 3 meters). It is situated in the field of this peculiar condenser, in which the distribution of lines of force and their direction changes, depending on different processes connected with the fall of snow and its horizontal and vertical movements under the influence of air currents.

The dynamics of the processes connected with strong winds (velocity up to 20 meters per second and more), and the influence of these processes on the electrical condition of the snow cause the reversed character of the field, as observed on the Fedchenko glacier.(This is described in greater detail in the author's monograph on the Fedchenko glacier (9)).

With regard to the problem of the charge of the earth's surface, the observations made on the Fedchenko glacier assume the character of supplementary material on the "balance" of countercurrent, which is computed by all authors only on the basis of observations in storm regions, and from point discharges observed experimentally at several points of the globe during thunderstorms. The observations on the Fedchenko glacier are of particular importance when we consider the high values of the field, possibly amounting to tens of thousands of volts per meter and occurring over a period of about three fourths of a year, sometimes for days on end.

It should be noted that (according to the well-known glaciologist N. L. Korzhenevskiy) such orographic, meteorological and climatological conditions are not at all unusual.

At the same time, if we take into consideration the intensity and continuity of the processes, such reversed electrical fields must have a definite effect on the preservation of the earth's charge, as long as this agrees with the hypothesis of Wilson and others, who connect the preservation of the negative charge of the earth with the reversed fields in zones of disturbance of the normal electrical field.

It is possible that the phenomenon observed on the Fedchenko glacier, if generalized for all regions with similar reversed fields formed under similar conditions of snowfall, will show its effect equal to that observed in storm regions at irregular intervals and not always definite as to its sign. It will be necessary then to make a "recomputation" of the balance of positive and negative currents, and, possibly, to make a general revision of the theory from a different viewpoint.

The author, having other facts and material at his disposal which can explain the negative charge of the earth's surface from a different viewpoint, intends to devote a special treatise to this question in the near future.

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[Appended figures follow.]

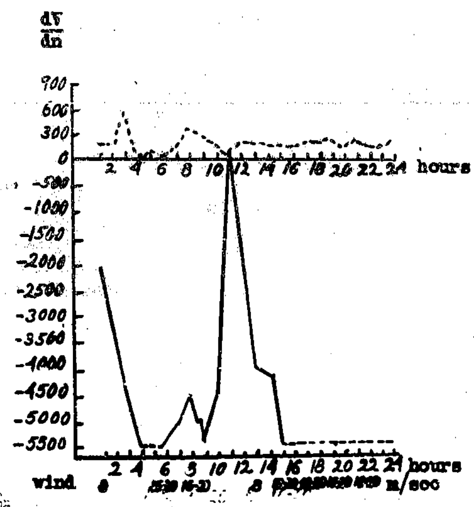

Figure 1. Variations of $\frac{dV}{dn}$ During Snowfall, 29 December 1943.

------- in Tashkent; ——— on the Fedchenko glacier; ---->500 V/m

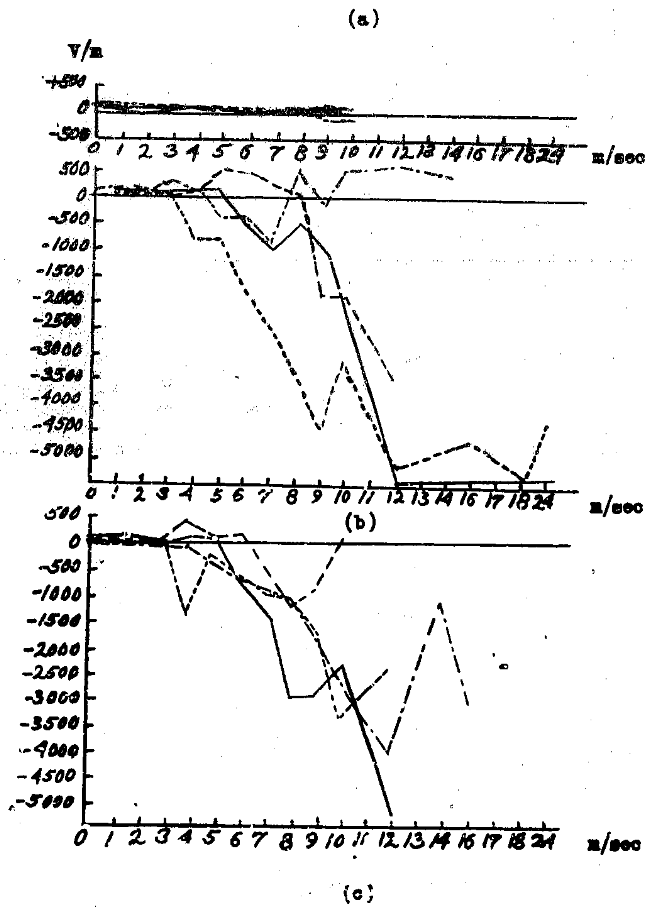

Figure 2, Relationship between $\frac{dV}{dh}$ and Wind Velocity on the Fedchenko Glacier.

(a) ——— June 1943; - - - - - July 1943; -------- August 1943; — - — September 1943

(b) ——— October 1943; — — — November 1943; -------- December 1943; — - — January 1944

(c) ——— February 1944; — — — — March 1944; -------- April 1944; — - — - — May 1943

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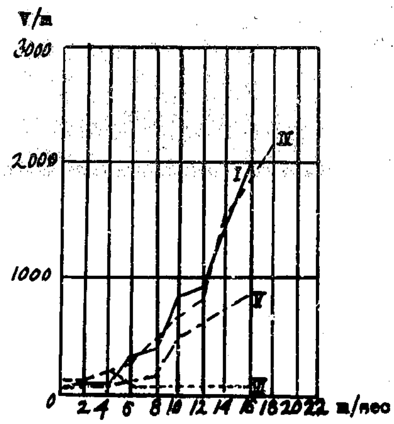
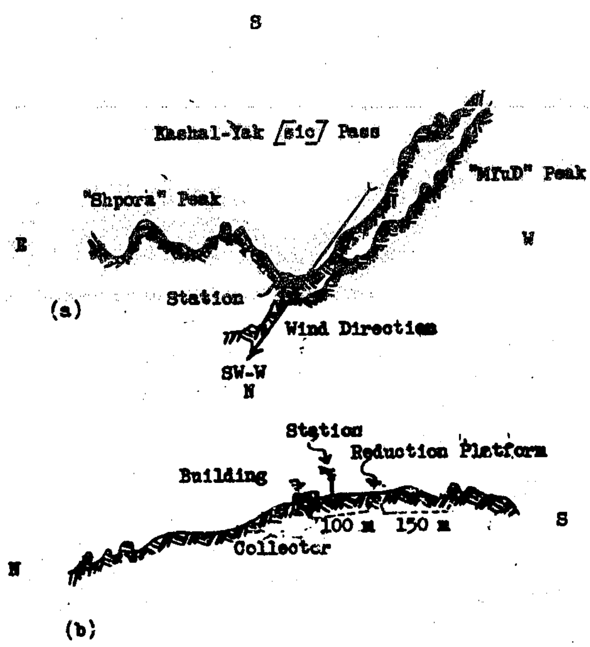


Figure 3. Relationship between $\frac{dV}{dn}$ and Wind Velocity on Dickson Island.

———— January; – – – – April; —·—·— May; ·············· June

Figure 4

(a) Location of Meteorological Station



(b) Location of Collector and Reduction Platform

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